Winter Cereal, Seeding Rate, and Intercrop Seeding Rate Effect on Red Clover Yield and Quality

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ABSTRACT

Diversification of corn (*Zea mays* L.)–soybean [*Glycine max* (L.) Merr.] cropping systems can be achieved by incorporating winter cereal grains. Winter cereal grain production systems in the northern USA are inefficient in respect to annual radiation capture because the majority of these fields lay fallow until the following cropping season. The addition of a red clover (*Trifolium pratense* L.) intercrop to winter cereal grains can supply forage and provide N to subsequent crops. The objective of this study was to determine the red clover dry matter (DM) and forage quality response to winter cereal species, cereal seeding rate, and red clover seeding rate. Winter wheat (*Triticum aestivum* L.) and triticale (×*Triticosecale* spp.) were seeded at 100, 200, 300, and 400 seed m^{-2} in October 2002 and 2003. In March, red clover was frost-seeded at 300, 600, 900, 1200, and 1500 seed m^{-2}. Red clover harvests in late summer, early fall, and the following spring yielded 6.2 to 8.5 Mg ha^{-1} DM. Winter cereal species only affected red clover DM in the following spring of 1 yr. Cereal seeding rates impacted DM within specific harvest periods, but had no effect on seasonal totals or spring DM. Increasing red clover seeding rates increased final DM yield in four of six harvests. Increasing red clover seeding rate had no consistent effect on forage quality. Producers that intercrop red clover in winter wheat or triticale should frost-seed at 900 to 1200 seed m^{-2} to maximize DM yield.

Diversifying corn–soybean cropping systems using winter cereal grains can maintain profitability (Exner and Cruse, 2001), break pest cycles (Cook, 1988), and improve yields of subsequent crops (Singer and Cox, 1998). Additionally, using a winter cereal grain as a companion crop during legume establishment can provide a cash grain and straw (Exner and Cruse, 2001) and reduce soil erosion (Kaspar et al., 2001), nitrate losses (Strock et al., 2004), and weed competition (Van Heemst, 1985). Utilizing a legume for the remainder of the growing season after cereal grain harvest can provide forage for livestock, weed suppression (Blaser et al., 2006; Mutch et al., 2003), and N for subsequent crops (Bruulsema and Christie, 1987; Hesterman et al., 1992; Singer and Cox, 1998). Red clover is an excellent choice for winter cereal grain intercrops because it tolerates shading (Blaser et al., 2006) and has similar feed value to alfalfa (*Medicago sativa* L. subsp. *sativa*) (Broderick et al., 2001). Understanding the influence of winter cereal grain management and red clover seeding rates on red clover DM production and forage quality can optimize management of this system.

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Research on the effects of legume stand density on forage quality are limited and primarily focused on alfalfa. Alfalfa studies using rates of 11 to 484 plants m^{-2} (Bolger and Meyer, 1983) and 4.5 to 50.4 kg seed ha^{-1} (Krueger and Hansen, 1974; Stout, 1998) found no effect of seeding rate on forage quality indicators. However, Volenec et al. (1987) and Cherney et al. (1986) reported that plant stem diameter decreased and stem in vitro dry matter digestibility (IVDMD) increased about 5% as first-year alfalfa stand densities increased from 11 to 172 plants m^{-2}. Cherney et al. (1986) also reported a decrease in alfalfa stem neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations as stand densities increased, yet there was no effect of stand density on IVDMD, ADF, or NDF when forage samples containing both stems and leaves were evaluated. Min et al. (2000) reported a quadratic response between seeding rate and alfalfa crude protein (CP) in the first harvest following the establishment year, but the effect diminished in a second harvest 60 d later.

Few studies have reported companion crop effects on forage legume quality. Results from a Minnesota study using alfalfa planted with barley (*Hordeum vulgare* L.) or oat (*Avena sativa* L.) had 0.5 to 2.4 g kg^{-1} less CP, 9 to 11 g kg^{-1} greater NDF, and 3 g kg^{-1} greater ADF than direct-seeded alfalfa when harvested twice in the establishment year (Brink and Marten, 1986). Data from companion crop studies that report silage quality of the combined winter or spring companion crop and the legume are not transferable to intercrop systems where the cereal grain and straw are harvested followed by sole legume production cycles. In cereal/legume intercrop systems, it is unclear how inter- and intraspecific competition affects DM production and forage quality during specific growth periods following cereal grain harvest. The objective of this study was to determine how winter cereal species and seeding rate and red clover seeding rate affected red clover DM production and forage quality.

MATERIALS AND METHODS

A winter cereal grain/red clover intercrop seeding rate study was conducted during the 2002–2004 and 2003–2005 growing seasons at the Iowa State University Agronomy and Agricultural Engineering Farm near Ames, IA (42° 00′ N, 93° 50′ W; elevation 341 masl). Treatments were arranged in a split-split-plot with four replicates with cereal species main plots, cereal seeding rate subplots, and red clover seeding rate sub-subplots. The experiment had an incomplete randomized block design in 2002–2004 because the 1200 and 1500 seed m^{-2} red clover

seeding rates were not planted in the 100 seed m^{-2} cereal seeding rate treatment due to space restrictions. The experimental design for 2003–2005 was a randomized complete block. The planted area for each cereal seeding rate was 7.6×22.9 m in 2002–2004 and 7.6×27.4 m in 2003–2005. Each red clover seeding rate treatment occupied 3.8×7.6 m in 2002–2004 and 3.8×9.1 m in 2003–2005.

Recently harvested soybean fields with Clarion loam soil (fine-loamy, mixed, mesic typic Hapludoll) in 2002–2004 and Canisteo silty clay loam soil (fine-loamy, mixed, superactive, calcareous, mesic Typic Haplaquoll) in 2003–2005 were prepared for planting with one pass of a tandem disk followed by one pass of a culti-packer roller. 'Kaskaskia' soft red winter wheat and 'Presto' triticale were planted at 100, 200, 300, and 400 seed m^{-2} on 11 Oct. 2002 and 1 Oct. 2003 using a tractor-mounted 7.6-m-wide Marliss[1] grain drill (Marliss Industries, Jonesboro, AR) with 19-cm row spacing. Both species were replanted at the target rates on 15 Oct. 2003 because of inadequate stands resulting from planter equipment malfunction. All plots were broadcast fertilized with 45 kg N ha^{-1} as NH_4NO_3 on 25 Mar. 2003 and 12 Mar. 2004. In 2003, wheat subplots were harvested on 16 July and triticale subplots were harvested on 22 July. In 2004, both wheat and triticale subplots were harvested on 15 July 2004.

'Cherokee' red clover was frost-seeded at 300, 600, 900, 1200, and 1500 seed m^{-2} using a tractor-mounted, 3.66-m-wide Gandy Model 1012T-TBM drop spreader (Gandy Co., Owatonna, MN) on 26 Mar. 2003 and 12 Mar. 2004 in each cereal subplot. Red clover stand densities were determined from four replicates by counting two 0.25-m^2 quadrats per sub-subplot following cereal grain harvest on 23 July 2003 and 21 July 2004. Red clover shoot DM was measured at $\approx 10, 25$, and 40 d during two growth periods after cereal harvest by clipping red clover 6 cm above the soil surface in two 0.25-m^2 quadrats on 24 July, 8 Aug., 22 Aug., 3 Sept., 17 Sept., and 1 Oct. 2003 and 26 July, 9 Aug., 23 Aug., 2 Sept., 16 Sept., and 4 Oct. 2004. The spring following establishment, red clover was harvested on 11 and 9 May 2004 and 2005 following the same protocol. Each successive harvest was sampled from a different, non-trafficked area of each sub-subplot. Shoot DM was oven dried at 60°C until a constant weight and ground using a Model-4 Wiley laboratory mill (Thomas Scientific, Swedesboro, NJ) fitted with a 1-mm screen. After each 40-d DM harvest, red clover was harvested mechanically with a Green Chopper Lacerator (Gruett's, Potter, WI) leaving a 6-cm stubble height. These harvests occurred on 22 and 23 Aug. 2003 and 2004, 1 and 4 Oct. 2003 and 2004, and 12 and 10 May 2004 and 2005. Red clover plant density was determined the spring following establishment by excavating and counting all plants in one 0.25-m^2 quadrat in each sub-subplot on 12 and 10 May 2004 and 2005. The spring red clover plant density and all DM measurements were obtained from three replicates.

Red clover DM from the two 40-d harvests after cereal grain harvest each year and the spring DM harvest was used to measure forage quality. Ground samples were analyzed for total N concentration using the Dumas combustion method (AOAC International, 2000). Crude protein was calculated by multiplying percentage N by 6.25. Forage digestibility was measured using the IVDMD method by Tilley and Terry (1963) as modified by Marten and Barnes (1980). The IVDMD procedure was performed on a 0.5-g subsample of each ground plant sample. The NDF analysis was performed using a 0.25-g

subsample. These subsamples were analyzed using Ankom's fiber analyzer F200 following the company's NDF protocol (Ankom Technology Corporation, Fairport, NY). Percentage DM was determined by drying 1 g of ground plant tissue at 105°C for 4 h and weighing. All forage quality results are reported on a DM basis.

Daily precipitation was recorded at a weather station located 1.5 km from the experimental site. Statistical analysis was performed using the PROC MIXED (method = type 3) procedure of the Statistical Analysis System (SAS Institute, 2002). Block and all block interactions were considered random effects, while cereal species, cereal seeding rate, and red clover seeding rate were considered fixed effects. Year and year $\times$ treatment interactions were significant for most variables, so data were analyzed and presented by year. A Fisher's protected LSD ($\alpha = 0.05$) was used for mean separation. All effects were considered significant if $P < 0.05$.

RESULTS AND DISCUSSION
Red Clover Dry Matter

Red clover frost-seeded in triticale yielded 67 and 59% less DM than red clover frost-seeded in wheat at 10- and 25-d harvests of the first red clover growth period in 2003 (Table 1). This difference was probably related to cereal phenology and canopy structure. First, wheat matured and was harvested 6 d earlier than triticale, allowing red clover plants in wheat 16 d of growth without competition from the grain canopy compared with 10 d for red clover following triticale. Second, during cereal growth, triticale canopies transmitted less light to the red clover intercrop than wheat (Blaser et al., 2006). Klebesadel and Smith (1959) reported that more competitive cereal species transmitted less light to a legume intercrop reducing legume stand density and DM production. At the 40-d harvest of the first growth period, red clover DM was no longer affected by species ($P = 0.063$). At the 10-d harvest of the first growth period, averaged across cereal species and red clover seeding rate, red clover DM increased 43% as cereal seeding rate decreased from 400 to 200 seed m^{-2} (Table 1).

Red clover seeding rate affected DM at the 10- and 25-d harvests in 2003 as biomass increased 438 and 120% when seeding rate increased from 300 to 1500 seed m^{-2} at these two sampling dates (Table 1). Red clover DM at 900 seed m^{-2} produced similar DM to the 1200 and 1500 seed m^{-2} treatments at the 25-d harvest of the first growth period and the 25- and 40-d harvests of the second growth period. No difference between these treatments was detected at the 40-d harvest of the first growth period ($P = 0.125$). Combining both 40-d harvests, red clover DM at the 300 seed m^{-2} seeding rate (2.60 Mg ha^{-1}) was lower than the rest of the red clover seeding rates, which were similar (3.34 Mg ha^{-1}). The difference between the 600 and 900 seed m^{-2} rate was 0.35 Mg ha^{-1}.

The first red clover growth period of 2004 also exhibited an early effect of cereal species. Red clover DM following triticale was 36% less than wheat at the 10 d harvest (Table 1). Cereal species were harvested on the same day, suggesting that greater light interception in triticale (Blaser et al., 2006) most likely contributed to

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[1] Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA.

Table 1. Mean red clover post grain harvest (PGH) density and dry matter (DM) for cereal grain (CG) species, seeding rate, and red clover (RC) seeding rate main effects from RC harvests at ≈10, 25, and 40 d during two growth periods following CG harvest in 2003 and 2004 near Ames, IA.

		DM					
		First growth period†			Second growth period		
Target seeding rate	PGH density	10 d	25 d	40 d	10 d	25 d	40 d
seed m^{-2}	plant m^{-2}	Mg ha^{-1}					
2003							
CG species							
Triticale	116b‡	0.11b	0.42b	1.03	0.39	1.10	1.83
Wheat	142a	0.33a	1.02a	1.91	0.32	0.93	1.61
LSD (0.05)	23	0.13	0.27	ns§	ns	ns	ns
CG seeding rate							
100	116¶	0.36a	0.92a	1.83	0.32	0.98	1.66
200	112	0.20ab	0.72ab	1.44	0.32	1.04	1.66
300	99	0.16b	0.54b	1.32	0.33	0.97	1.68
400	111	0.15b	0.60b	1.43	0.35	1.02	1.70
LSD (0.05)	ns	0.06	0.21	ns	ns	ns	ns
RC seeding rate							
300	67d	0.08d	0.41c	1.17	0.30b	0.88c	1.43c
600	116c	0.18c	0.64b	1.46	0.33ab	1.01b	1.68b
900	140b	0.26b	0.82ab	1.56	0.37a	1.13a	1.93a
1200	138b	0.22bc	0.79ab	1.56	0.36ab	1.00b	1.74ab
1500	187a	0.35a	0.94a	1.60	0.39a	1.05ab	1.82ab
LSD (0.05)	19	0.07	0.21	ns	0.07	0.12	0.23
2004							
CG species							
Triticale	98a	0.46b	1.39	2.93	0.21	1.17	2.73
Wheat	103a	0.72a	1.73	3.48	0.20	1.22	2.83
LSD (0.05)	ns	0.14	ns	ns	ns	ns	ns
CG seeding rate							
100	98b	0.89a	2.12a	3.70a	0.19	1.06	2.62c
200	101ab	0.69b	1.86b	3.74a	0.19	1.17	2.73bc
300	108a	0.44c	1.18c	2.80b	0.20	1.24	2.75b
400	104ab	0.34c	1.08c	2.60b	0.23	1.30	3.01a
LSD (0.05)	10	0.13	0.27	0.50	ns	ns	0.13
RC seeding rate							
300	46e	0.30e	1.21d	2.52c	0.17b	0.93c	2.37d
600	76d	0.46d	1.36cd	3.05b	0.19b	1.15b	2.65c
900	90c	0.61c	1.61bc	3.23b	0.17b	1.15b	2.82bc
1200	123b	0.74b	1.72ab	3.55a	0.22ab	1.40a	3.12a
1500	166a	0.85a	1.90a	3.68a	0.26a	1.34a	2.92b
LSD (0.05)	10	0.09	0.25	0.30	0.06	0.15	0.20

† First growth period harvests occurred on 24 July, 8 and 22 Aug. 2003, and 26 July and 9 and 23 Aug. 2004, respectively. Second growth period harvests occurred on 3 and 17 Sept., 1 Oct. 2003, 2 and 16 Sept., and 4 Oct. 2004, respectively.
‡ Means followed by same letter within a column, year, and factor are not significantly different $P < 0.05$.
§ ns, not significant.
¶ CG seeding rate data analysis excluded 1200 and 1500 seed m^{-2} RC seeding rates; all other 2003 data include 1200 and 1500 seed m^{-2} RC seeding rates, but excludes all data from 100 seed m^{-2} CG seeding rate.

the lower red clover DM. This effect diminished rapidly and was not detected again for the remainder of the growing season. Increasing cereal seeding rate from 100 to 400 seed m^{-2} decreased red clover DM yield 62, 49, and 30% for the 10, 25, and 40 d harvests, respectively (Table 1). The residual effect of cereal seeding rates on red clover DM decreased with time, suggesting a compensatory-type growth response in red clover and a diminishing effect of the cereal grain companion crop.

Red clover DM responded to increased red clover seeding rate at the 10-d harvest and across most red clover seeding rates at the 25- and 40-d harvests in 2004 (Table 1). Maximum DM was produced with the 1500 seed m^{-2} seeding rate at the 10-d harvest of the first growth period in 2004, but yields were not different from the 1200 seed m^{-2} seeding rate at the 25- or 40-d harvests. Red clover DM increased as red clover seeding rate increased for each cereal seeding rate, except at the 1200 and 1500 seed m^{-2} red clover seeding rates in the

300 and 400 seed m^{-2} cereal seeding rates (data not presented). This cereal seeding rate by red clover seeding rate interaction is most likely attributed to increased competition for light and water.

Red clover DM response to red clover seeding rate during the second growth period of 2004 was similar to the first growth period, except the 1200 seed m^{-2} seeding rate produced similar or greater DM than the 1500 seed m^{-2} seeding rate (Table 1). Increasing cereal seeding rate in the first growth period decreased red clover DM. The opposite response was observed at the 40-d harvest of the second growth period, with 13% greater red clover DM as cereal seeding rate increased from 100 to 400 seed m^{-2} ($P = 0.007$). Rainfall during the first and second growth period in 2004 totaled 84 and 77 mm, respectively. Consequently, soil water probably did not influence the red clover response. This response was more pronounced than the effect observed in 2003, probably because only 38 mm of rainfall occurred during

the first 40-d growth period and only 12 mm of rainfall was received from 11 Aug. until 10 Sept. A total of 100 mm of rainfall occurred during the second 40-d period, but the majority of this was received during the second half of the growth period, which may have been too late for a significant plant response. The results from 2004 indicate that higher winter cereal seeding rates suppress red clover DM production during the growth period following cereal harvest. Producers using this type of intercrop system at the recommended winter cereal seeding rate (300–400 seed m^{-2}) could shorten the harvest interval during the first growth period after cereal harvest and lengthen the interval during the second growth period when the potential for compensatory growth occurs. Shortening the first harvest interval after cereal grain harvest by five to 10 d could also minimize weed seed production. However, the compensatory response we observed in 2004 followed normal rainfall. Also, it is unclear how much forage quality would change during a longer second growth period during the establishment year.

Spring Red Clover Stand Densities and Dry Matter

Red clover stand densities following winter cereal grain harvest in 2003 averaged 12 to 22% of target seeding rate and ranged between 67 and 187 plants m^{-2} (Table 1). After digging and counting plants the spring after frost-seeding, red clover densities were found to increase 30 to 46% from the density counts obtained after cereal grain harvest the previous summer. Overall, 21 to 40% of frost-seeded red clover established mature plants with actual stand densities ranging from 116 to 314 plants m^{-2} across red clover seeding rates (Table 2).

Similar to 2004, plant densities in the spring of 2005 also increased from the density counts obtained after cereal grain harvest during the establishment year, although the increase was not as large (3–28%). Red clover stand densities recorded after cereal grain harvest in 2004 averaged 11 to 15% of target densities with a range of 46 to 166 plants m^{-2} (Table 1). A cereal seeding rate effect was observed in spring 2005 as red clover densities increased from 109 to 137 plants m^{-2} with increased cereal seeding rates. Greater separation among treatments was observed for red clover seeding rate, with densities ranging from 64 to 172 plants m^{-2} (Table 2). The increase in red clover plants from July

(post-grain-harvest densities) of the establishment year to this measurement period suggest temporal responses to environmental conditions can be large. Greater incident light after cereal harvest or rainfall in the late summer and fall may penetrate hard seed coats or move seed into more suitable microenvironments for germination. Singer et al. (2006) reported 19 and 23% frost-seeded red clover mortality in winter wheat in Iowa from a spring to post-cereal-grain-harvest measurement date, but did not present data on red clover density the following spring.

In the spring of 2004, red clover following triticale, averaged across cereal and red clover seeding rate, produced 3.14 Mg ha^{-1} DM, 11% higher than red clover following wheat. This was most likely due to an increase in red clover stand densities in triticale from the 2003 post-cereal-grain-harvest average of 116 plants m^{-2} to the spring 2004 count of 235 plants m^{-2} compared with 142 and 187 plants m^{-2} following wheat. Averaged across species and cereal seeding rate, DM responded up to 900 red clover seed m^{-2} (Table 2). The 900 seed m^{-2} rate produced higher DM yields at the second 40-d harvest in 2003, the spring harvest in 2004, and 0.67 Mg ha^{-1} more DM than the 600 seed m^{-2} rate combined across the three harvests. Spring 2005 DM averaged 2.49 Mg ha^{-1} across all treatments and had no species, cereal, or red clover seeding rate effects. Although red clover stand densities were affected by seeding rate, DM production was similar ($P = 0.057$, Table 2). Rainfall during April and early May 2004 and 2005 was 74 and 82 mm, and average air temperature in April 2004 and 2005 (11.7 and 12.8°C) was above normal (10.2°C, Fig. 1). The lack of a DM response to red clover seeding rate in 2005 may not be related to spring rainfall or air temperature, but may be related to fall DM yield and air temperature following harvest. Air temperature was above average in October and November 2004 (12.1 and 5.7 vs. 11.1 and 2.7°C) and DM yields in the second 40-d period averaged 2.78 Mg ha^{-1}, which was 62% higher than the average DM yield during the second growth period in 2003. No cereal seeding rate × red clover seeding rate interactions for DM were detected in this study. Consequently, producers intercropping red clover in winter wheat or triticale should use the optimum winter cereal seeding rates (Blaser et al., 2006) in this system.

Table 2. Mean red clover (RC) plant density and dry matter (DM) from different RC seeding rates, averaged across cereal grain (CG) species and CG seeding rate, in the spring of 2004 and 2005 near Ames, IA. Red clover was frost-seeded into winter wheat and triticale planted at 100, 200, 300, and 400 seed m^{-2} in spring of 2003 and 2004.

		2004		2005	
	Target seeding rate	Density†	DM‡	Density	DM
	seed m^{-2}	plants m^{-2}	Mg ha^{-1}	plants m^{-2}	Mg ha^{-1}
RC seeding rate	300	116e§	2.82b	64d	2.27
	600	166d	2.83b	98c	2.51
	900	204c	3.15a	125b	2.48
	1200	255b	2.95ab	147b	2.62
	1500	314a	3.12a	172a	2.55
LSD (0.05)		31	0.26	25	ns¶

† Counted on 12 and 10 May 2004 and 2005.
‡ Harvested on 11 and 9 May 2004 and 2005.
§ Means followed by same letter within a column are not significantly different $P < 0.05$.
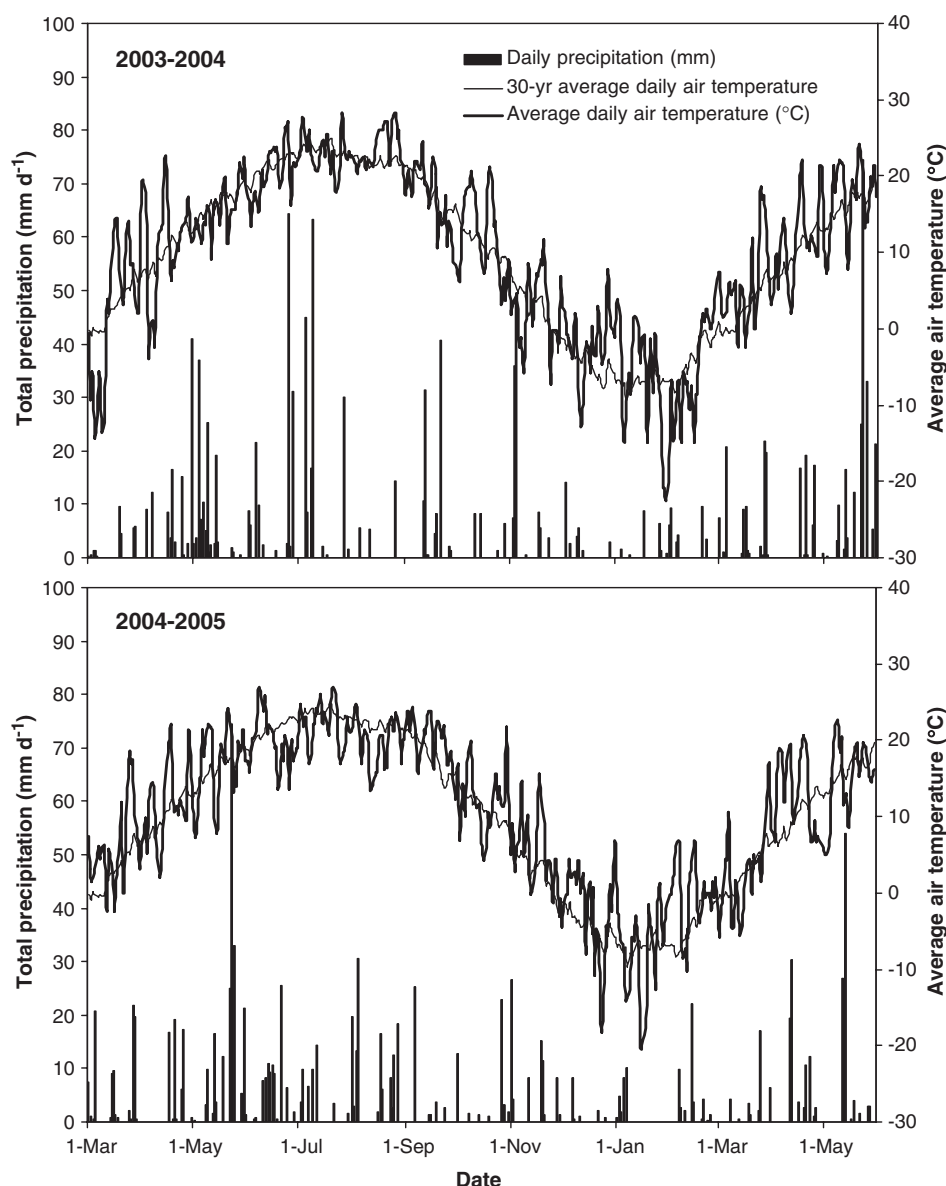¶ ns, not significant.

Fig. 1. Daily precipitation and average air temperature for 1 Mar. 2003 to 30 May 2004, 1 Mar. 2004 to 30 May 2005, and the 30-yr average air temperature near Ames, IA.

Red Clover Forage Quality

Red clover CP concentrations ranged from 196 to 265 g kg^{-1} in 2003–2004. Averaged across cereal and red clover seeding rate, red clover CP following triticale was 14 and 1% higher than CP following wheat at the first forage harvest following cereal grain harvest ($P = 0.023$) and in the spring 2004 harvest ($P = 0.009$, data not presented). Red clover CP decreased 6% as red clover seeding rate increased from 300 to 1500 seed m^{-2} (67–187 plants m^{-2}, Table 3). Min et al. (2000) reported a decrease in CP as alfalfa densities increased to >100 plants m^{-2}, suggesting that plant densities above a critical maximum may reduce CP concentrations.

In 2003–2004, NDF and IVDMD concentrations ranged from 298 to 325 and 650 to 758 g kg^{-1}, respectively (Table 3). No main effects or interactions were

detected during the first harvest period in 2003 for NDF or IVDMD. During the second harvest period, a species × cereal seeding rate interaction was detected for NDF and IVDMD because red clover established in triticale at 200 seed m^{-2} had higher NDF and lower IVDMD than the 300 and 400 seed m^{-2} treatments, while red clover established in wheat had similar NDF and IVDMD across cereal seeding rates. During the second harvest period, red clover DM at the 300 seed m^{-2} red clover seeding rate had lower NDF concentration (298 g kg^{-1}) than the other red clover rates (318 g kg^{-1}), and IVDMD was lower in the 1500 (650 g kg^{-1}) compared with the 300 and 600 (673 g kg^{-1}) seed m^{-2} red clover seeding rates.

In 2004–2005, CP, NDF, and IVDMD concentrations ranged from 177 to 234, 240 to 345, and 720 to 789 g kg^{-1} (Table 3). During the first growth period in

Table 3. Mean red clover (RC) neutral detergent fiber (NDF), in vitro dry matter digestibility (IVDMD), and crude protein (CP) from different RC seeding rates, averaged across cereal grain (CG) species and CG seeding rate. Red clover was harvested after two 40-d growth periods following CG harvest and in the spring following the establishment year near Ames, IA, from 2003–2005.

	Target seeding rate	Harvest 1†			Harvest 2‡			Spring§		
		NDF	IVDMD	CP	NDF	IVDMD	CP	NDF	IVDMD	CP
	seed m^{-2}				g kg^{-1}					
				2003–2004						
RC seeding rate	300	309	686	209a¶	298b	679a	256	320	758	230
	600	316	684	206ab	313a	667ab	261	323	752	234
	900	305	686	203abc	319a	661bc	258	325	749	227
	1200	314	678	200bc	316a	665abc	256	316	755	233
	1500	318	670	196c	322a	650c	265	323	748	227
LSD (0.05)		ns#	ns	8	13	17	ns	ns	ns	ns
				2004–2005						
RC seeding rate	300	331c	726	177	245d	786	227	244bc	771ab	234
	600	336bc	725	180	252cd	788	224	240c	772ab	232
	900	344ab	720	179	256bc	789	227	244bc	769a	230
	1200	345a	720	179	270a	783	219	249ab	764bc	230
	1500	343ab	725	181	260b	784	225	253a	760c	230
LSD (0.05)		9	ns	ns	8	ns	ns	8	8	ns

† Harvested on 22 and 23 Aug. 2003 and 2004.
‡ Harvested on 1 and 4 Oct. 2003 and 2004.
§ Harvested on 11 and 9 May 2004 and 2005.
¶ Means followed by same letter within a column and year are not significantly different $P < 0.05$.
# ns, not significant.

2004, the 100 and 200 seed m^{-2} cereal seeding rate lowered CP and IVDMD and increased NDF concentration (171, 708, and 353 g kg^{-1}, respectively) compared with the 300 and 400 seed m^{-2} rate (188, 739, and 327 g kg^{-1}, respectively). The residual effect from the higher cereal seeding rates resulted in less DM with higher forage quality. Red clover DM in the lowest red clover seeding rate had lower NDF than the highest seeding rate in both harvests during 2004 and the spring 2005 harvest (Table 3). Other differences among red clover seeding rate were observed for NDF but were not as consistent. Red clover spring IVDMD concentrations < 900 seed m^{-2} were higher than the highest red clover rate. A cereal seeding rate × red clover seeding rate interaction for the 2004–2005 spring NDF and IVDMD concentrations showed inconsistent results among cereal seeding rates (data not presented), but exhibited a general increase in NDF and decrease in IVDMD as red clover seeding rate increased.

CONCLUSIONS

Frost-seeded red clover DM from harvests in the late summer and early fall and an additional harvest the following spring can provide producers with 6.2 to 8.5 Mg ha^{-1} DM. Winter cereal species only affected red clover DM in the spring of 1 yr. Cereal seeding rate impacted DM within specific harvest periods, but the impact diminished with time and had no effect on seasonal totals or spring DM. Nevertheless, producers may maximize red clover DM production following winter cereals seeded at optimum rates by shortening the harvest interval during the harvest immediately following cereal grain harvest and lengthening the interval during the second harvest period. If near average rainfall occurs early during the second growth period, lengthening this interval may exploit a compensatory

growth response. Increasing red clover seeding rate increased DM yield in three of four 40-d harvests and one of two spring harvests. Cereal species, seeding rate, and red clover seeding rate had no consistent effect on red clover forage quality. Producers intercropping red clover in winter wheat or triticale should frost-seed at 900 to 1200 seed m^{-2} to maximize DM yield.

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